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DEEP-TILLAGE INVESTIGATIONS

on Compacted Soil in the Cotton Area of Louisiana

AGRICULTURAL RESEARCH SERVICE
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Prepared in

Soil and Water Conservation Research Division
Agricultural Research Service

in cooperation with the

Louisiana Agricultural Experiment Station

DEEP-TILLAGE INVESTIGATIONS ON COMPACTED SOIL IN THE COTTON AREA OF LOUISIANA[1]

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INTRODUCTION

Deep-tillage research in Louisiana was brought about by the compaction problem found in northern Louisiana fields of the Mississippi River delta plains cotton area.

During periods of sparce rainfall, cotton growth was retarded, and the plants wilted excessively in isolated parts of the fields, and then burned. Farmers refer to these affected parts as "hot spots." Investigations showed zones of compaction usually beginning 5 inches below the surface and extending 18 inches deep. These are natural hardpans and not pans made by the traffic of farm implements. The condition was found in loam soils, principally Commerce Silt Loam. Field observations indicated an interference with water movement through the soil in the recharging of deep soil moisture during the winter.

Research investigations for evaluating and solving this problem were begun in the early winter of 1953 and cover the crop years 1954-58, inclusive.

The research investigations were made on the assumption that moisture intake, retention, and transmission characteristics of soils are often limiting factors in production.

EXPERIMENTAL AREA

The three experimental sites are located in northern Louisiana on the Mississippi Alluvial Plain (delta plains). This consists of a mass of sediments filling an entrenched drainage valley system that was formed during the melting of the Pleistocene glacial ice sheets in the north.

Prior to completion of a stable levee system, major streams meandered over the area, changing their courses from time to time. Low meander belt ridges and natural levees of silty and sandy segments are in evidence from channel deposits of rivers and their tributaries and crevasses.

The general soil textures are graded, with the coarser textures at the streambanks and the finer textures away from them. This general pattern of deposition is somewhat altered by flooding of crevasses; this flooding scours out sloughs and redistributes the sediments. The sloughs are then refilled with sediments by later floods. Because of this pattern of deposition, the texture throughout the soil profile is not uniform.

RAINFALL

The distribution of rainfall is more important for cotton production than the annual total, which, in the Louisiana cotton area, is approximately 52 inches per year. When percolation is not impaired by compaction, rainfall is usually sufficient in the winter months to recharge the deep soil moisture. During April, May, and June, maximum moisture is required to produce the stalk. Fruiting begins in July. During July, August, and September, although sufficient moisture is required to develop the boll, too much moisture is not desired, for two reasons: Excessive moisture promotes luscious foliage, and this promotes boll rot and interferes with insecticide application.

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[1] Cooperative undertaking of the Soil and Water Conservation Research Division, ARS, USDA, and the Louisiana Agricultural Experiment Station.

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Annual rainfall for the tests is depicted in Appendix Figures 4 through 8. Rainfall distribution was adequate during the growing periods of 1955, 1957, and 1958. Moisture deficiencies during the 1954 and 1956 growing seasons were due to uneven rainfall distribution over the year. According to Van Bavel,[5] moisture deficiency can be expected for the Louisiana cotton area 5 out of 10 years during June, July, August, and September.

PROCEDURE

In accordance with Louisiana practice, in this experiment cotton was planted in the middle of April on rows approximately 5 inches high and 40 inches apart and the crop was harvested in late September and during October.

The plots were deep tilled in the fall when the soil was dry, to obtain maximum shattering of the natural hardpans. The prevalent method of land preparation (conventional tillage), with which deep tillage was compared, consists of disking the field and forming the rows with a middlebuster. To further pulverize the soil, after the rows are formed they are reversed by splitting with a middlebuster, and the halves of two adjacent rows become one row in the middle.

Deep Tillage Treatments

Three methods of deep tillage on compacted alluvial soils of the cotton area of Louisiana were investigated. The three methods were:

(1) Soil Lifted 1 Level 18 Inches Deep.--This is a modified method of subsoiling which lifts and cracks the soil to a depth of 18 inches with 24-inch subsurface sweeps mounted on subsoiling shanks. The sweeps are set on 40-inch centers imparting a 2 1/2-inch lift as they move through the soil. See Figure 1.

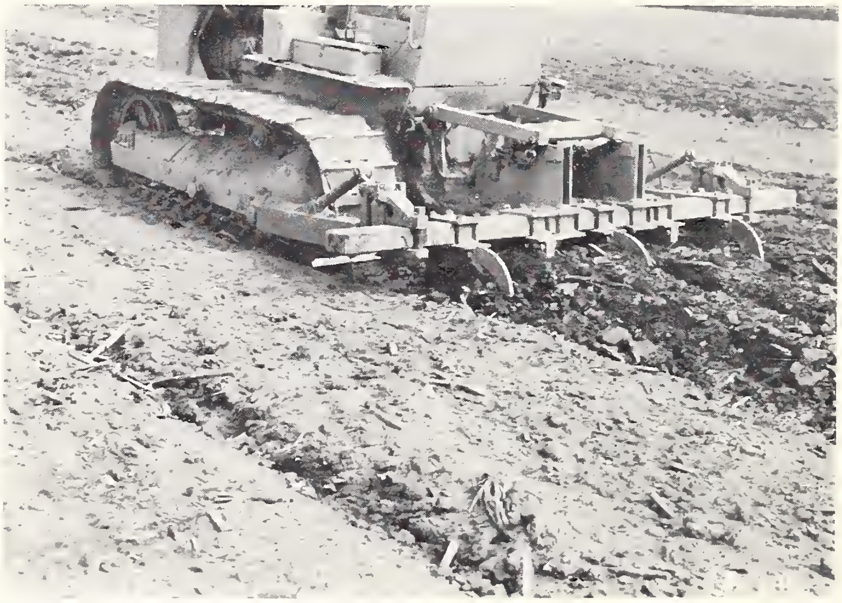

Figure 1.--Tool bar equipped with subsoiling shank and sweep for the Lifting treatment. Each sweep is 24 inches wide and has a $2\frac{1}{2}$-inch lift. (St. Joseph, La., fall of 1953.)

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[5] Van Bavel, C. H. M. Drought and Water Surplus in Agricultural Soils of the Lower Mississippi Valley Area. U. S. Dept. Agr. Tech. Bul. 1209, 93 pp. 1959.

(2) Soil Edged 12 and 18 Inches Deep.--This method consists of plowing either 12 or 18 inches deep with a moldboard plow. The furrow slice is turned approximately 90 degrees and set on edge to place the soil layers in an almost vertical position. See Figure 2.

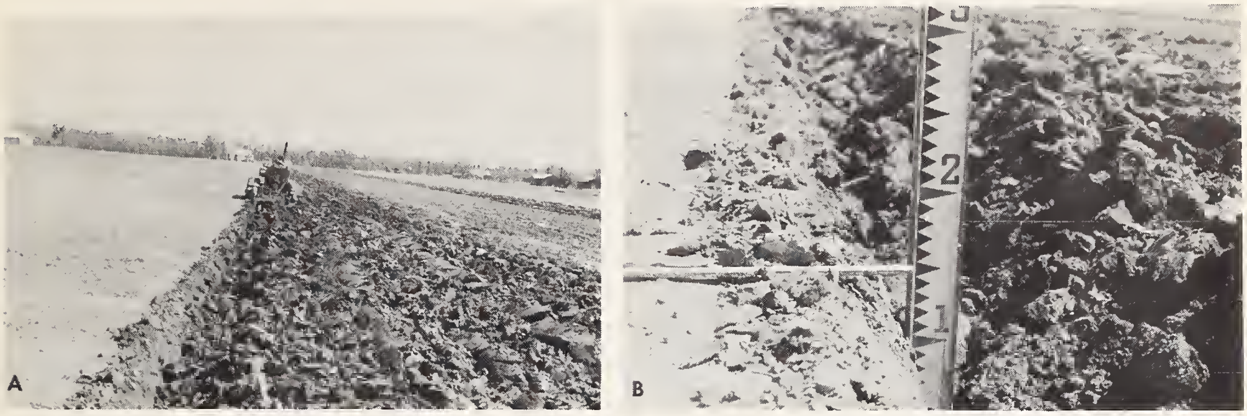

Figure 2.--A., Deep-tillage plowing for Edged 18 Inches treatment; B., closeup shot of measurement of plowing depth. (Wilkerson Plantation, Newellton, La., spring of 1955.)

(3) Soil Mixed.--In this method the top 14 inches of soil is mixed by scarifying with a heavy field cultivator equipped with closely spaced chisels. This treatment was used on some of the earlier tests but was discontinued because it overpulverized the surface and in turn retarded the infiltration of rainwater. See Figure 3.

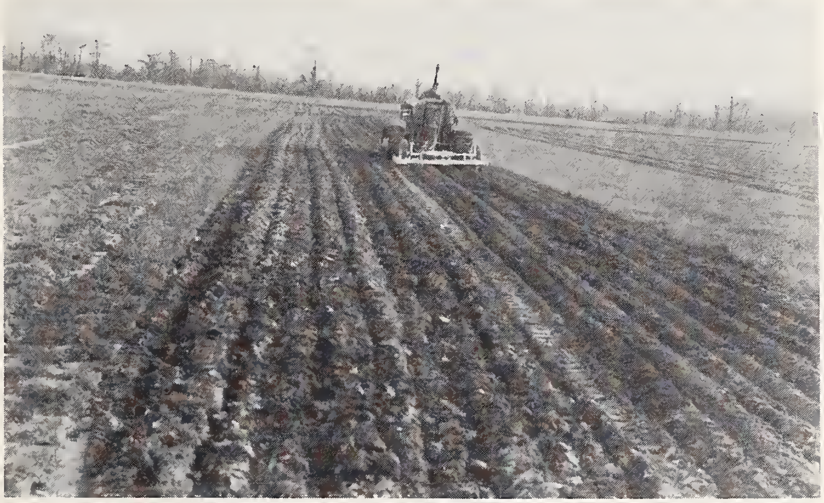

Figure 3.--Mixing by scarifying 14 inches deep. (St. Joseph, La., early winter of 1953.)

All plots were left flat during the winter. Early in the spring they were disked and placed in rows with 40-inch centers, which were reversed once, then planted, fertilized, and cultivated in the conventional manner. The center two rows of each plot were harvested for plant response comparison. This procedure left a buffer strip for removing the border effect between plots.

The experiments are replicated random plot designs. In LA-5 the plots were split in order to make a residual study to determine the duration of the deep-tillage treatments. With the exception of the conventionally treated, and those left for deep-tillage residual studies, the plots were deep tilled annually in the early winter after the rows were removed by disking and dragging.

Procedure at Individual Sites

Sites with typical compaction problems were selected for the experimental work. Those of LA-1 and LA-5 were located at the Northeast Louisiana Experiment Station, St. Joseph. LA-7 was an outfield experiment located in the same parish on the Wilkerson Plantation, Newellton. At each of the locations the compacted layers, or (natural) hardpans, occurred in narrow strips approximately 40 feet wide across the fields and 150 feet apart. In periods of sparce rainfall cotton burned on the land with these (natural) hardpans, "hot spots."

All of the experiments were located on medium-textured soil, principally of Commerce Silt Loam.

LA-1 - N.E. La. Expt. Sta., St. Joseph (Commerce Silt Loam).--This experiment included the conventional and the three deep-tillage treatments, in five replications.

The cotton was grown in 6-row plots 20 feet wide and 250 feet long. After deep tillage in the early winter of 1953, the first crop was grown in 1954. Each deep-tilled plot was treated annually through the 1957 crop and then left for a 1-year residual study. In treating the area for the 1957 crop, the plots of Mixed 14 Inches were converted to Edged 12 Inches.

LA-5 - N.E. La. Expt. Sta., St. Joseph (Commerce Silt Loam).--This experiment included the conventional and the three deep-tillage treatments, in four replications.

The cotton was grown in 12-row plots 40 feet wide and 250 feet long. Each plot was completely treated in 1954 for the 1955 crop. Beginning with soil preparation for the 1956 crop (in 1954 and 1955), the deep tillage was arranged so that only half of each plot was treated annually. The other half was treated biannually for a 1-year residual study. In treating the area for the 1957 crop, the Mixed 14 Inches plots were converted to Edged 12 Inches. The area was not treated for the 1958 crop, but was left for 1- and 2-year residual studies.

LA-7 - Wilkerson Plantation, Newellton (Commerce Silt Loam).--This outfield experiment included the conventional and the three deep-tillage treatments, in two replications in 1954 and four replications in 1956.

The cotton was grown in 12-row plots 40 feet wide and 2,000 feet long.

Treatment Evaluation

Effects on soil physical properties, soil moisture content during the growing season, and crop yields were used to evaluate the tests. Cotton yields were measured in pounds of seed cotton per acre.

Soil physical measurements included bulk density, total porosity, percent large pores, and water permeability. In addition, particle size analyses (hydrometer method and mechanical sieving) were made to catalog the soil characteristics.

For soil physical determinations and comparison between treatments, the plots were sampled 18 inches deep (in increments of 3 inches) at selected periods with a Uhland-type sampler (3-inch cores).

Soil moisture studies were made in 1954 and 1955 with moisture blocks and in 1956 and 1957 with the gravimetric method. At selected locations of the plots, soil moisture was gravimetrically measured to a depth of 3 feet during the growing season. Resistance readings of gypsum blocks were used to indicate moisture changes in the soil.

The relation of crop response, soil physical changes, and soil moisture content to deep tillage was considered in evaluating the tests.

RESULTS

Crop Response

LA-1 - N.E. La. Expt. Sta., St. Joseph.--Following are yield data for this experiment concerning 4 years of annual treatments and a 1-year residual study:

Treatment	Yield of Seed Cotton Per Acre				
	1954	1955	1956	1957	1958, 1-Year Residual
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Conventional-------------	2,022	3,022	2,488	1,684	1,706
Lifted 1 Level-----------	2,857	2,744	3,449	1,732	1,787
Edged 18 Inches----------	2,614	2,753	3,076	1,455	1,797
Mixed 14 Inches----------	1,817	2,898	2,387	[1]1,278	1,874

[1] Treatment converted to Edged 12 Inches.

Moisture stress was a problem in 1954 and 1956, as rainfall distribution was poor in these years. The following tabulation gives the increases obtained in 1954 and 1956 over the conventionally treated plots:

Treatment	Yield of Seed Cotton Per Acre			
	Increase		Decrease	
	1954	1956	1954	1956
	Pounds	*Pounds*	*Pounds*	*Pounds*
Lifted 1 Level--------------------------	835**	961**	--	--
Edged 18 Inches-------------------------	952*	588*	--	--
Mixed 14 Inches-------------------------	--	--	205	101

**Significant 1-percent level.
*Significant 5-percent level.

There were no significant increases or decreases in yields in 1955, 1957, and 1958, all years of good rainfall distribution.

LA-5 - N.E. La. Expt. Sta., St. Joseph.--Following are yield data for this experiment, including the annually treated and residual plots; yields of 1958 are for 1- and 2-year residual studies:

Treatment	1955[1]	Yield of Seed Cotton Per Acre					
		1956		1957		1958	
		Annual Treatment	1-Year Residual	Annual Treatment	1-Year Residual	1-Year Residual	2-Year Residual
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Conventional-------	3,014	1,411	1,623	1,396	1,259	1,628	1,663
Lifted 1 Level-----	2,965	3,194	2,278	1,331	1,305	1,903	1,858
Edged 18 Inches----	2,668	2,516	2,535	1,394	1,503	1,873	1,785
Mixed 14 Inches----	3,095	1,667	1,691	[2] 1,184	1,173	1,688	1,848

[1] Test inaugurated.
[2] Treatment converted to Edged 12 Inches.

In the one year of moisture stress (1956) increases were obtained over the conventionally treated plots, as follows:

Treatment	Increase in Yield of Seed Cotton Per Acre	
	Annual Treatment	1-Year Residual
	Pounds	*Pounds*
Lifted 1 Level------------------------------	1,783**	655
Edged 18 Inches----------------------------	1,106**	912*
Mixed 14 Inches----------------------------	256	68

**Significant 1-percent level.
*Practically significant 5-percent level.

The Lifted 1 Level treatment gave the greatest increase of the annually treated plots (1,783 lb.) and the Edged 18 Inches treatment gave the greatest increase of the 1-year residual study. There were no significant increases in yields in 1955, 1957, and 1958, all years of adequate, evenly distributed rainfall.

LA-7 - Wilkerson Plantation, Newellton.--In addition to the station experiments (LA-1 and LA-5), this large outfield experiment was in effect in 1954 and 1956, both years of high moisture stress. Yield data from this experiment are presented below:

Treatment	Yield of Seed Cotton Per Acre	
	1954	1956[1]
	Pounds	*Pounds*
Conventional-------------------------------	2,177	3,307
Lifted 1 Level------------------------------	2,722	3,715
Edged 18 Inches----------------------------	2,657	3,304
Mixed 14 Inches----------------------------	2,305	3,488

[1] Area was formed in 1955 to remove a drainage factor and may have had some tillage effect on the 1956 crop.

The following tabulation gives the 1954 and 1956 increases over the conventionally treated plots:

Treatment	Increase in Yield of Seed Cotton Per Acre	
	1954	1956
	Pounds	*Pounds*
Lifted 1 Level	545	408
Edged 18 Inches	480	-3
Mixed 14 Inches	128	181

Increases followed the same pattern as LA-1 and LA-5, with the exception of the Edged 18 Inches treatment in 1956. They were not quite significant at the 5-percent level.

Soil Moisture Data

LA-1 and LA-5 - N.E. La. Expt. Sta., St. Joseph.--Moisture desorption analyses indicated that the soils of these two experiments contained 25 to 30 percent by weight at field capacity and approximately 8 to 12 percent by weight at the wilting point. These limits varied considerably because of differences in soil texture.

Crop Year 1954 (LA-1)

Deep tillage in the early winter of 1953 greatly increased soil moisture storage over the winter. Observations made on April 1, 1954, showed almost saturated soil in the Lifted plots at 36 inches. But the soil in the Conventional plots was too dry to be pulled from the hole with an auger. Gravimetric moisture samples on May 17, 1954, indicated a difference of nearly 7 percent by weight between the Lifted and Conventional plots. Appendix Figure 9 depicts moisture conditions at this time (2-leaf-stage cotton) for all treatments from 6 to 36 inches deep.

Biweekly to 10-day resistance readings of the moisture blocks from June 1 to August 25 indicated that both Lifted and Edged treatments had higher moisture contents than the Conventional and Mixed treatments. Soil variations made it impossible to obtain a good calibration of the moisture blocks. Appendix Figures 10 and 11 depict resistance readings for all treatments at the 24- and 36-inch depths, respectively. The resistance readings reflect only moisture trends. A resistance reading of 3,000 ohms is equivalent to 16 to 17 percent moisture by weight.

Crop Year 1955 (LA-1)

Gravimetric measurements made in early May indicated that the soil profile had been recharged with moisture late in the winter.

Low rainfall was recorded in June and biweekly moisture block readings from June 6 to August 19 depicted some differences in moisture at the greater depths. On June 24 the blocks on the Conventional plots at the 24-inch depth had a reading of 3,000 ohms resistance (equivalent to 16 to 17 percent moisture by weight). The Edged and Lifted plots did not reach 3,000 ohms until July 5. At the 36-inch depth the 3,000-ohm reading was reached as follows: Conventional, June 28; Mixed, July 12; Lifted, July 19.

The block readings indicated ample moisture in all plots at the greater depths until the middle of July, after which time rains were frequent enough to maintain ample moisture in the 12-inch soil zones. See Appendix Figure 12, which gives the combined results for LA-1 and LA-5.

Crop Year 1955 (LA-5)

The spring and summer resistance readings of LA-5 concurred with those of LA-1, for all treatments. See Figure 12, which gives the combined results for LA-1 and LA-5.

Crop Year 1956 (LA-1 and LA-5)

The infrequency of gravimetric sampling from May 23 through August 7 prevented a close study of the moisture-removal pattern. The Lifted and Edged plots in LA-1 and LA-5 (annual treatment) contained more moisture early in the crop season than the Conventional plots. These differences appeared to continue without interruption throughout the growing season. See Appendix Figure 13.

LA-5 Residual Studies.--In LA-5 the Residual study plots showed the following: At the 18- to 24-inch sampling depths there was little difference in moisture content between the several deep-tillage treatments. The Lifted treatment, however, was slightly superior to other deep-tillage treatments in the Retreated plots, slightly inferior in the Residual plots. The Residual Edged 18 Inches treatment was as effective in storing moisture as the Retreated Edged 18 Inches treatment, verifying yield data for 1956, a dry year.

Crop Year 1957 (LA-1 and LA-5)

The 1957 gravimetric sampling depicted several soil moisture factors. Adequate moisture was present in a large percentage of root zone throughout the growing season. Early gravimetric measurements showed that soil moisture was recharged during the winter at the deeper zones on the deep-tilled plots. On April 23 the Lifted plots contained 26.5 percent moisture at the 36-inch depth; the Edged, 24.0 percent; and the Conventional, 21.3 percent. Following the heavy May rains, the first reading in June showed an increase in moisture in the Edged plots. The increase was almost equal to that of the Lifted plots, indicating that the land preparation for planting had less effect on water intake in the Edged plots. Rainfall for June and July was 13 1/2 inches. Despite decreased transpiration losses due to cloudy days and high humidity during this period, there was a marked decrease in moisture content at the greater depths. See Appendix Figure 14.

LA-5 Residual Studies.--A graphic comparison of the 30- to 36-inch depth (Appendix Figure 15) is presented for the following treatments: Residual--Edged 18 Inches and Lifted; Retreated--Edged 18 Inches and Lifted; and Conventional. At the beginning of the growing season the Residual treatments contained almost as much moisture as the Retreated plots, but showed some fluctuation as the season progressed. The Conventional plots approached wilting point a few days earlier than the deep-tilled plots. Then, in early July the Residual plots were almost as dry as the Conventional. However, near the end of July there was greater response to the heavy rains in the Residual plots, and their moisture content was almost as great by August as the Retreated plots.

The above soil moisture determinations in LA-1 and LA-5 indicate that deep tillage effectively increases infiltration in the winter, enabling a greater recharge of soil moisture. This was also reflected in the yield data for 1954 and 1956, both years of moisture stress.

Soil Physical Response
(LA-1 and LA-5 - N.E. La. Expt. Sta., St. Joseph)

Crop Year 1956

Results of physical analyses on quadruplicate soil cores taken in March 1956 at the depths of 3 to 6 inches, 8 to 11 inches, and 13 to 16 inches, showed no detectable changes due to deep tillage.

The water-retarding layers ("hot spots") in the Conventional plots were not characterized by high bulk densities, yet deep tillage improved soil moisture relations and increased crop yields.

Crop Year 1957

In 1957 these areas were sampled in duplicate at 6- to 9-inch and 12- to 15-inch depths. No changes resulting from treatment were reflected by the bulk density measurements, but a slight decrease in permeability and percent large pores occurred. Moisture measurements in the early spring, nevertheless, indicated that deep tillage effectively increased infiltration in the winter, enabling a greater recharge of deep subsoil moisture.

The following is an average particle size analysis of the soils in the test areas: Clay, 20 to 30 percent; silt, 30 to 50 percent; and sand, 30 to 40 percent.

SUMMARY AND CONCLUSIONS

The deep-tillage investigations on Commerce Silt Loam soil containing restricting layers ("hot spots") indicate that deep tillage is effective in years of moisture stress. The soil moisture data indicated that the compacted areas interfered with the recharge of deep soil moisture during the winter. The Edged and Lifted 1 Level treatments dispersed the compaction and facilitated (statistically significant) the deep soil moisture recharge by increasing infiltration of rainwater in the winter months. In this capacity the Mixed treatment was not effective.

Yield data indicated that both the Edged and Lifted 1 Level treatments substantially increased yields when moisture deficiency was a problem (1954 and 1956). Increases in yields ranged from 835 to 1,783 pounds per acre for the Lifted 1 Level treatment and from 592 to 1,106 for the Edged. Lifting was more effective the first crop year following treatment than later. Edging was more effective the second crop year following treatment than the first year following. There was nomeasurable significant change in soil physical properties between the treated and untreated plots. Other factors which may affect water intake, such as soil particle arrangement, were not measured.

The Louisiana cotton area can expect periods of moisture stress June through September in 5 of 10 years.[6] In these years of moisture stress deep tillage will pay dividends, since yields are increased by one-half bale or more per acre and current deep-tillage costs run from $7 to $10 per acre on a contract basis. Therefore, a profit of at least $50 per acre can be expected from deep tillage 5 out of 10 years.

APPENDIX

Figures 4 to 15, constituting graphs, are presented on the following pages as an appendix part of this report:

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[6] See footnote 5.

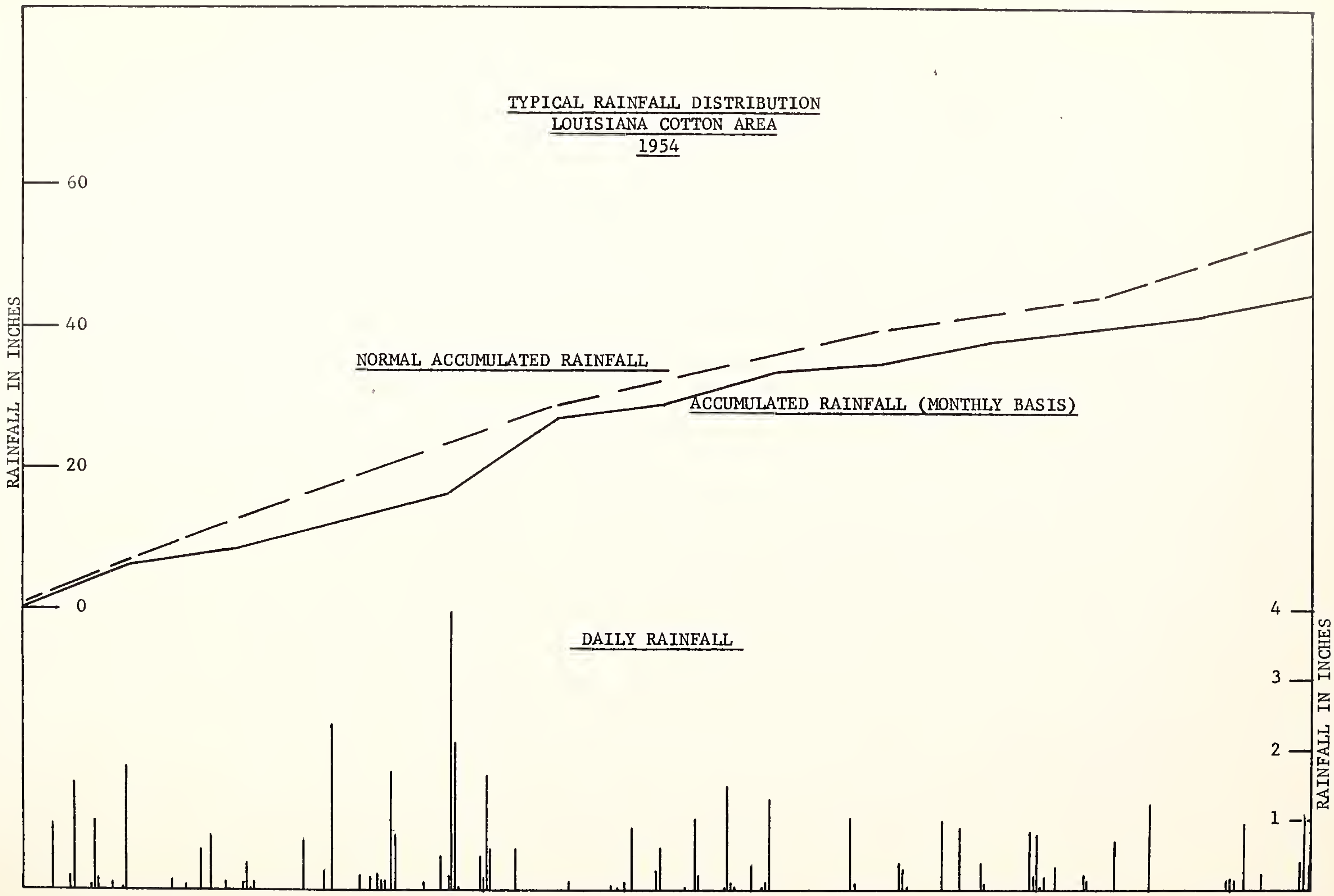

TYPICAL RAINFALL DISTRIBUTION
LOUISIANA COTTON AREA
1954
RAINFALL IN INCHES
60
40
20
0
NORMAL ACCUMULATED RAINFALL
ACCUMULATED RAINFALL (MONTHLY BASIS)
DAILY RAINFALL
RAINFALL IN INCHES
4
3
2
1

Figure 4

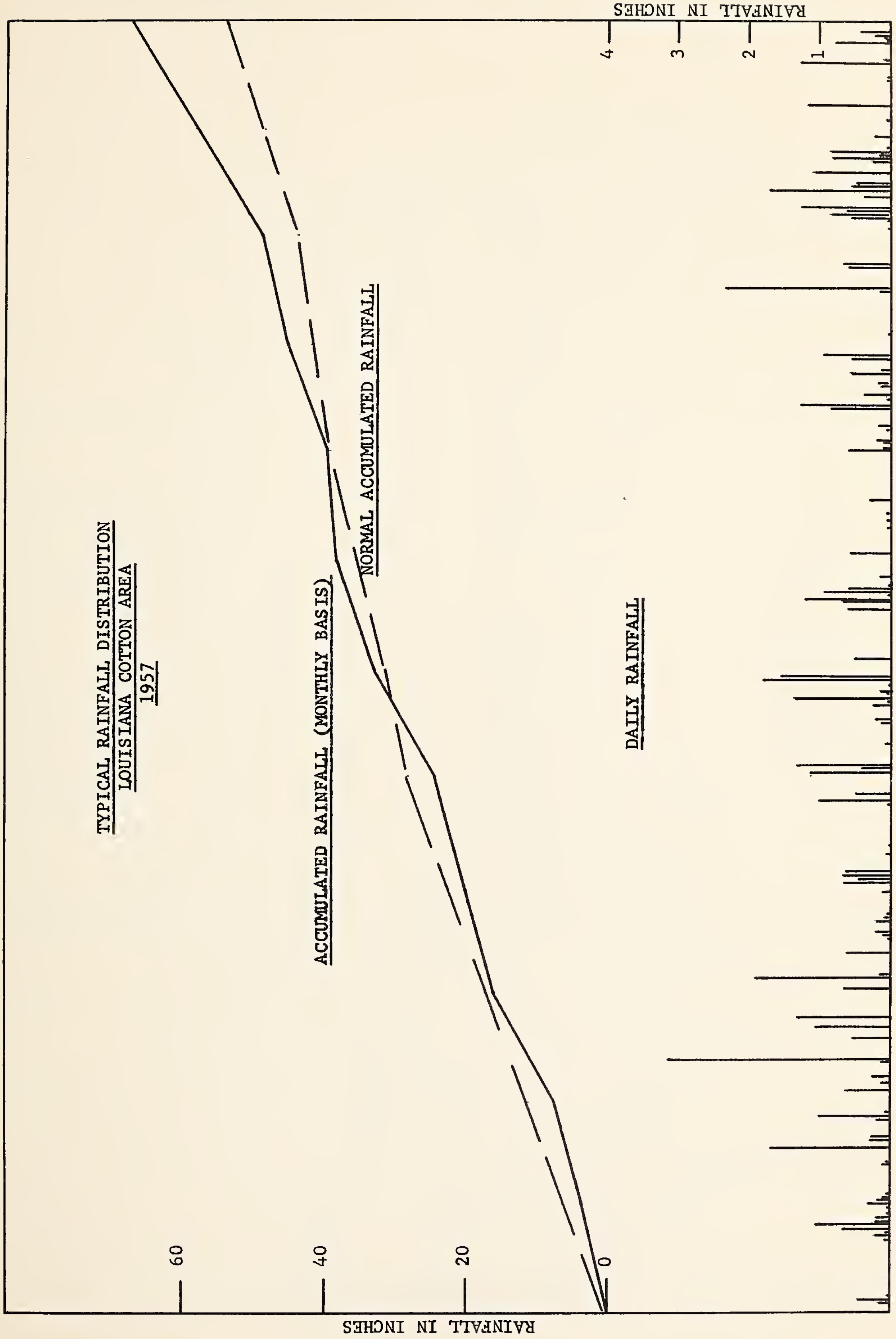

TYPICAL RAINFALL DISTRIBUTION
LOUISIANA COTTON AREA
1957
ACCUMULATED RAINFALL (MONTHLY BASIS)
NORMAL ACCUMULATED RAINFALL
DAILY RAINFALL
RAINFALL IN INCHES
0
20
40
60
RAINFALL IN INCHES
1
2
3
4

Figure 5

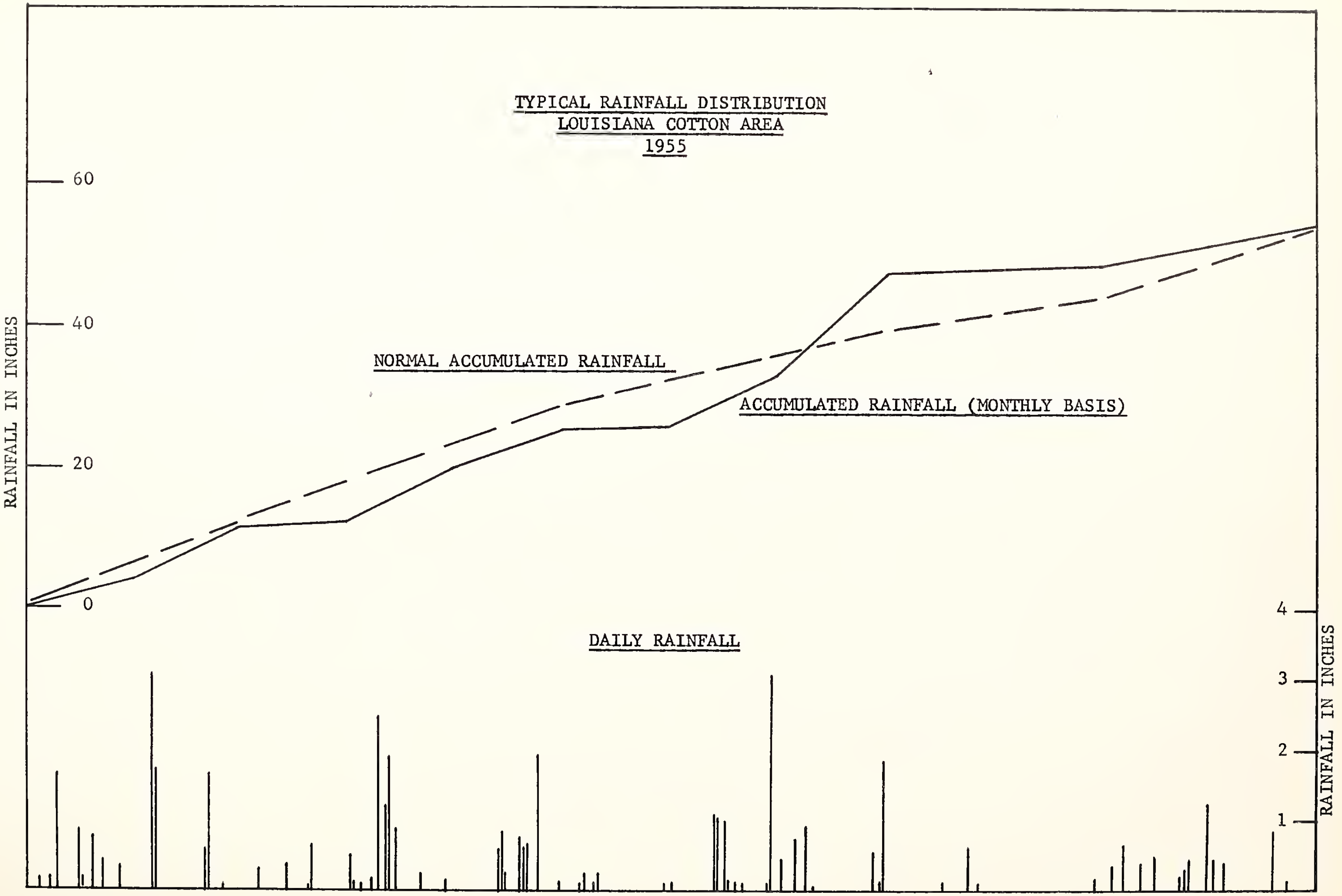
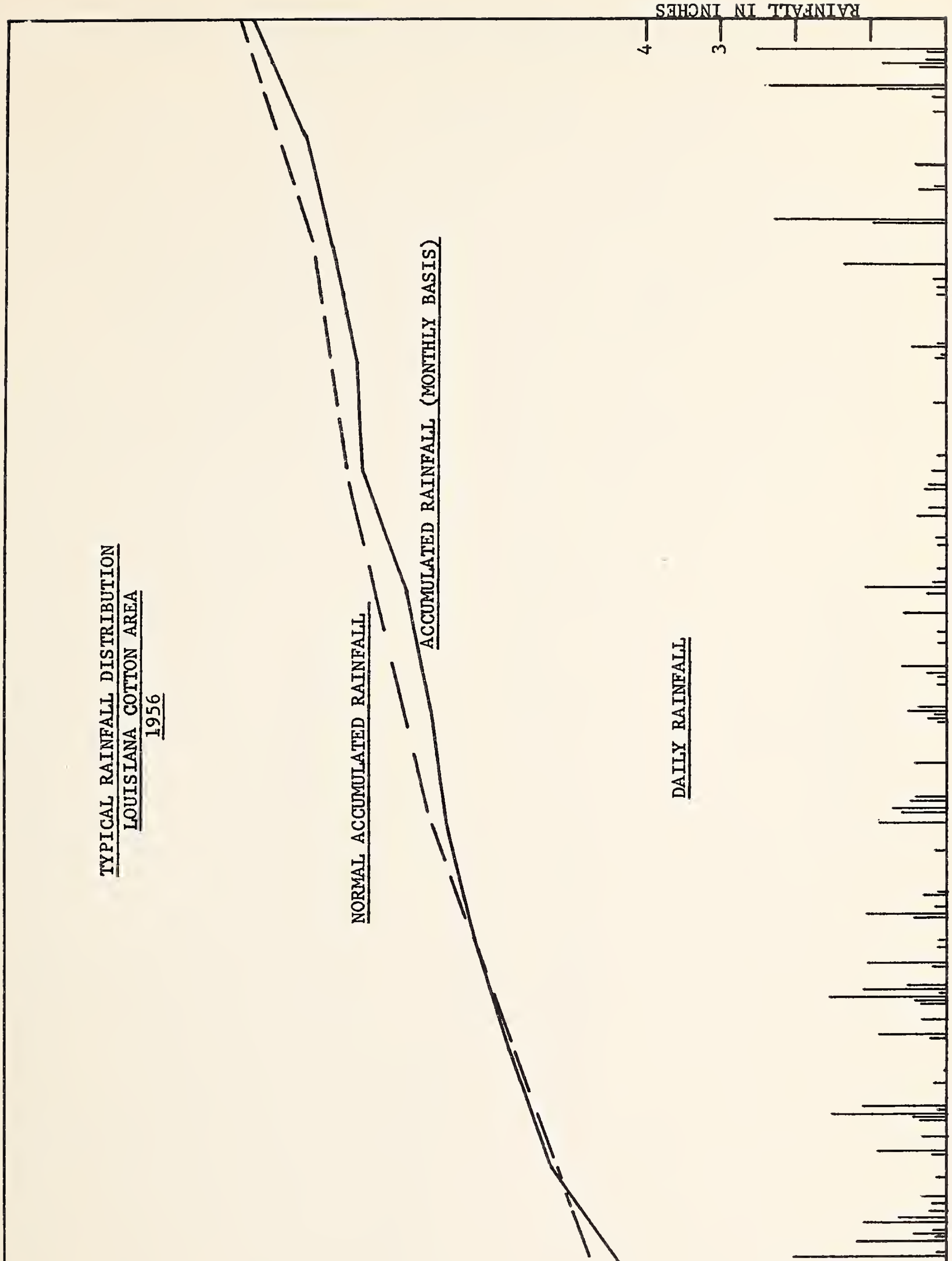

TYPICAL RAINFALL DISTRIBUTION
LOUISIANA COTTON AREA
1955
NORMAL ACCUMULATED RAINFALL
ACCUMULATED RAINFALL (MONTHLY BASIS)
DAILY RAINFALL
RAINFALL IN INCHES
0
20
40
60
RAINFALL IN INCHES
1
2
3
4

Figure 6


TYPICAL RAINFALL DISTRIBUTION
LOUISIANA COTTON AREA
1956
NORMAL ACCUMULATED RAINFALL
ACCUMULATED RAINFALL (MONTHLY BASIS)
DAILY RAINFALL
RAINFALL IN INCHES
0
20
40
60
RAINFALL IN INCHES
4
3

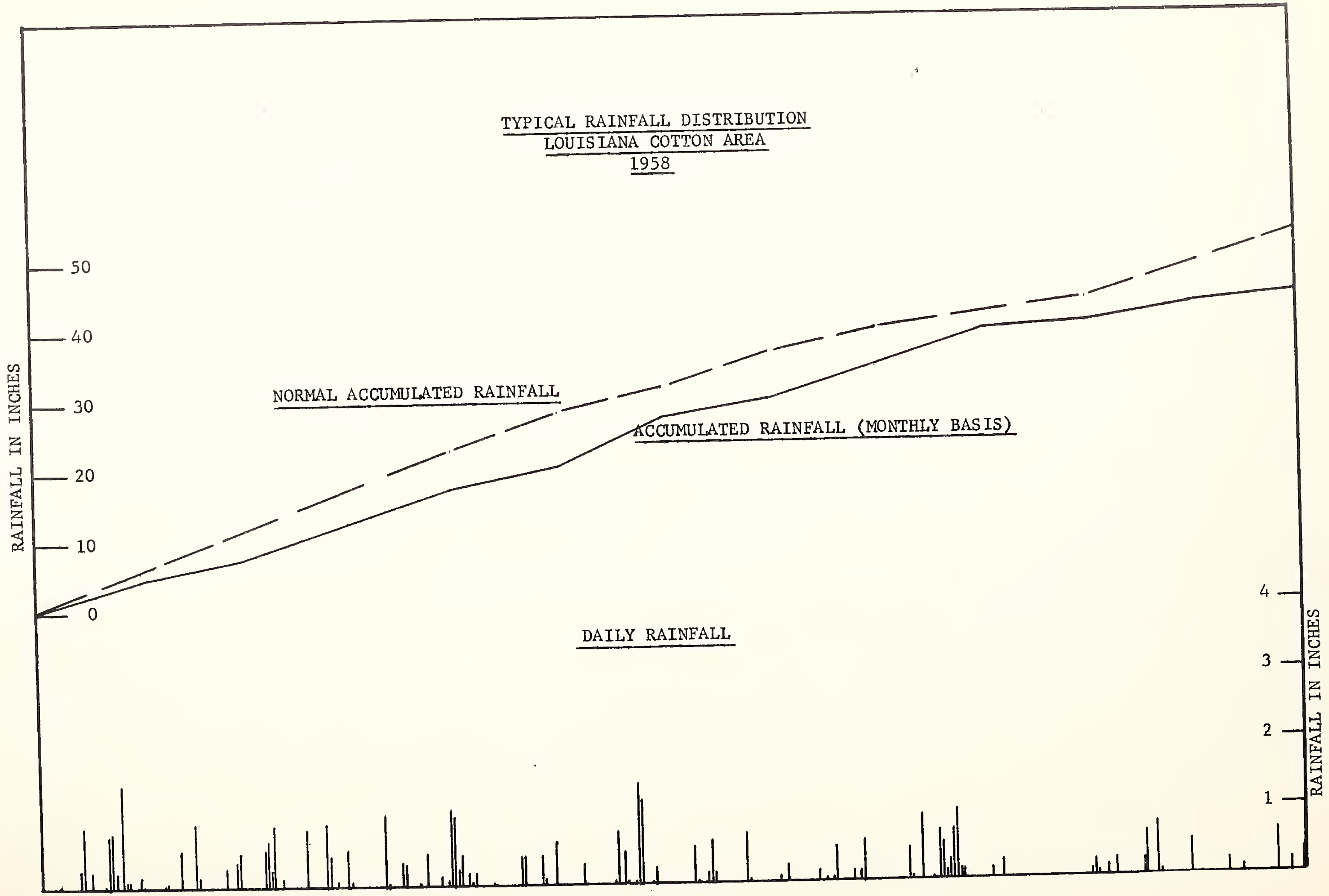

TYPICAL RAINFALL DISTRIBUTION
LOUISIANA COTTON AREA
1958
NORMAL ACCUMULATED RAINFALL
ACCUMULATED RAINFALL (MONTHLY BASIS)
DAILY RAINFALL
RAINFALL IN INCHES
50
40
30
20
10
0
RAINFALL IN INCHES
4
3
2
1

Figure 8

DEEP-TILLAGE EFFECTS ON MOISTURE CONTENT

COTTON TEST AREA - ST. JOSEPH, LOUISIANA

MAY - 1954

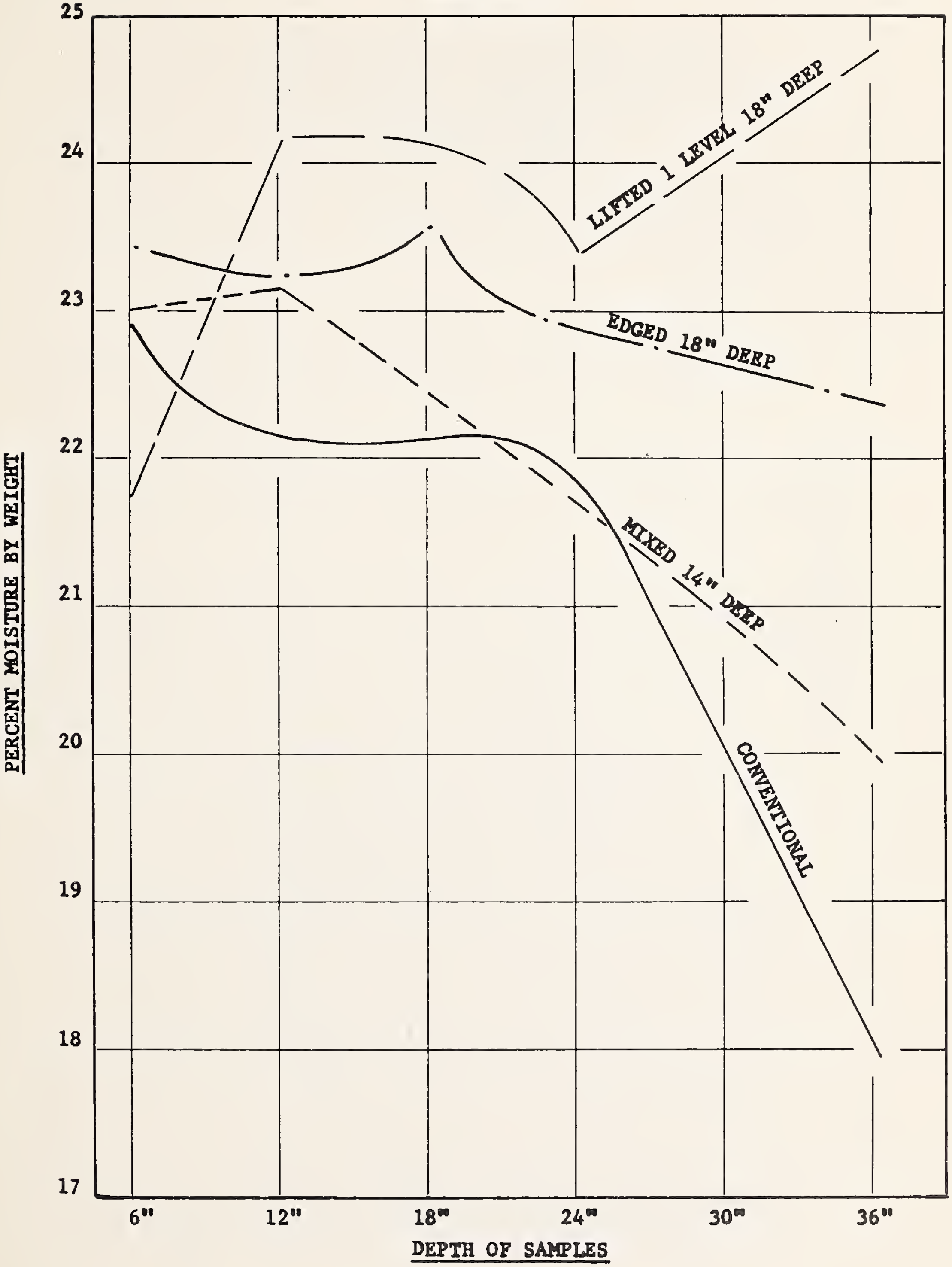


Figure 9

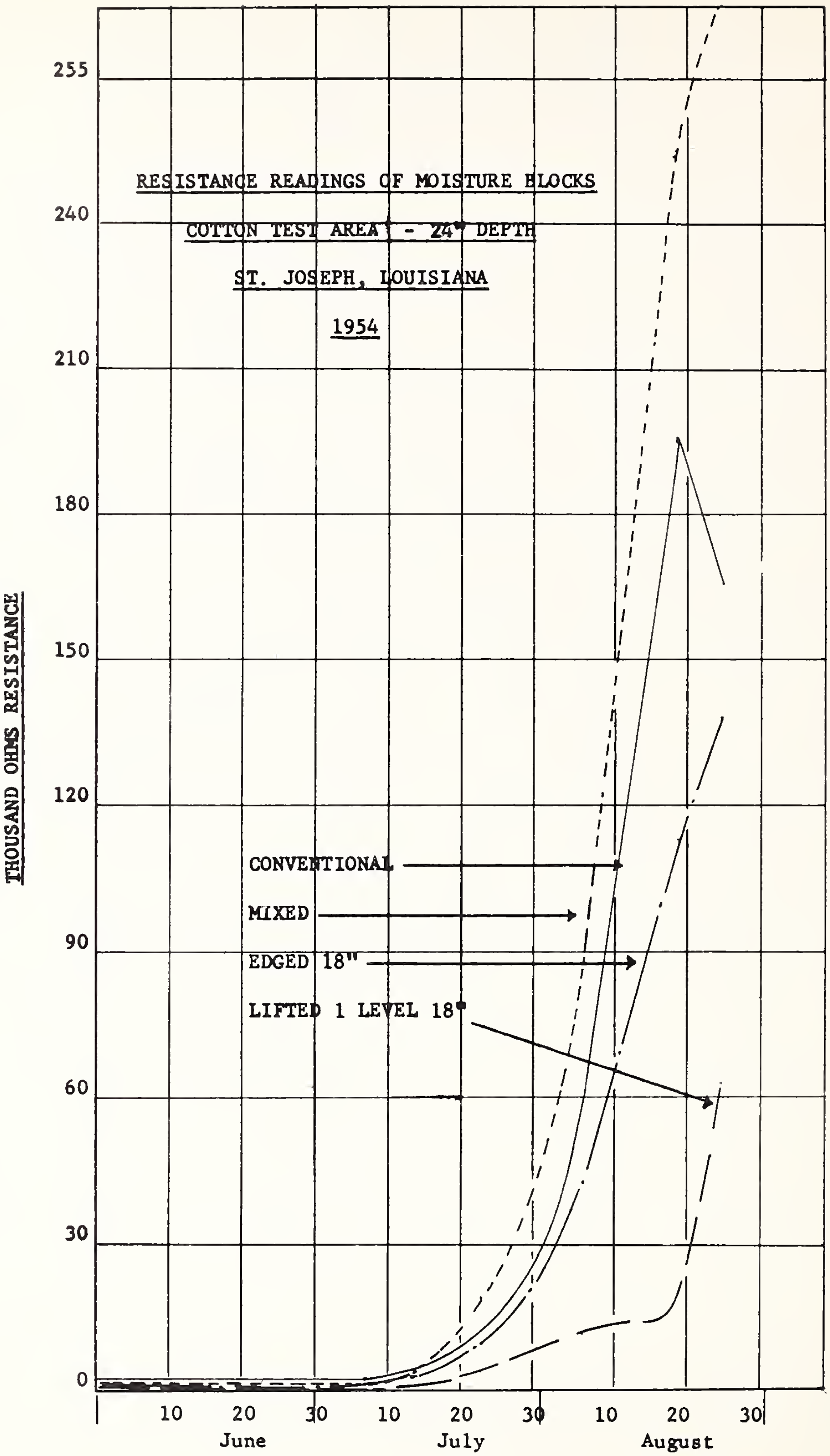
RESISTANCE READINGS OF MOISTURE BLOCKS
COTTON TEST AREA I - 24" DEPTH
ST. JOSEPH, LOUISIANA
1954
THOUSAND OHMS RESISTANCE
255
240
210
180
150
120
90
60
30
0
CONVENTIONAL
MIXED
EDGED 18"
LIFTED 1 LEVEL 18"
10
20
30
10
20
30
10
20
30
June
July
August

Figure 10

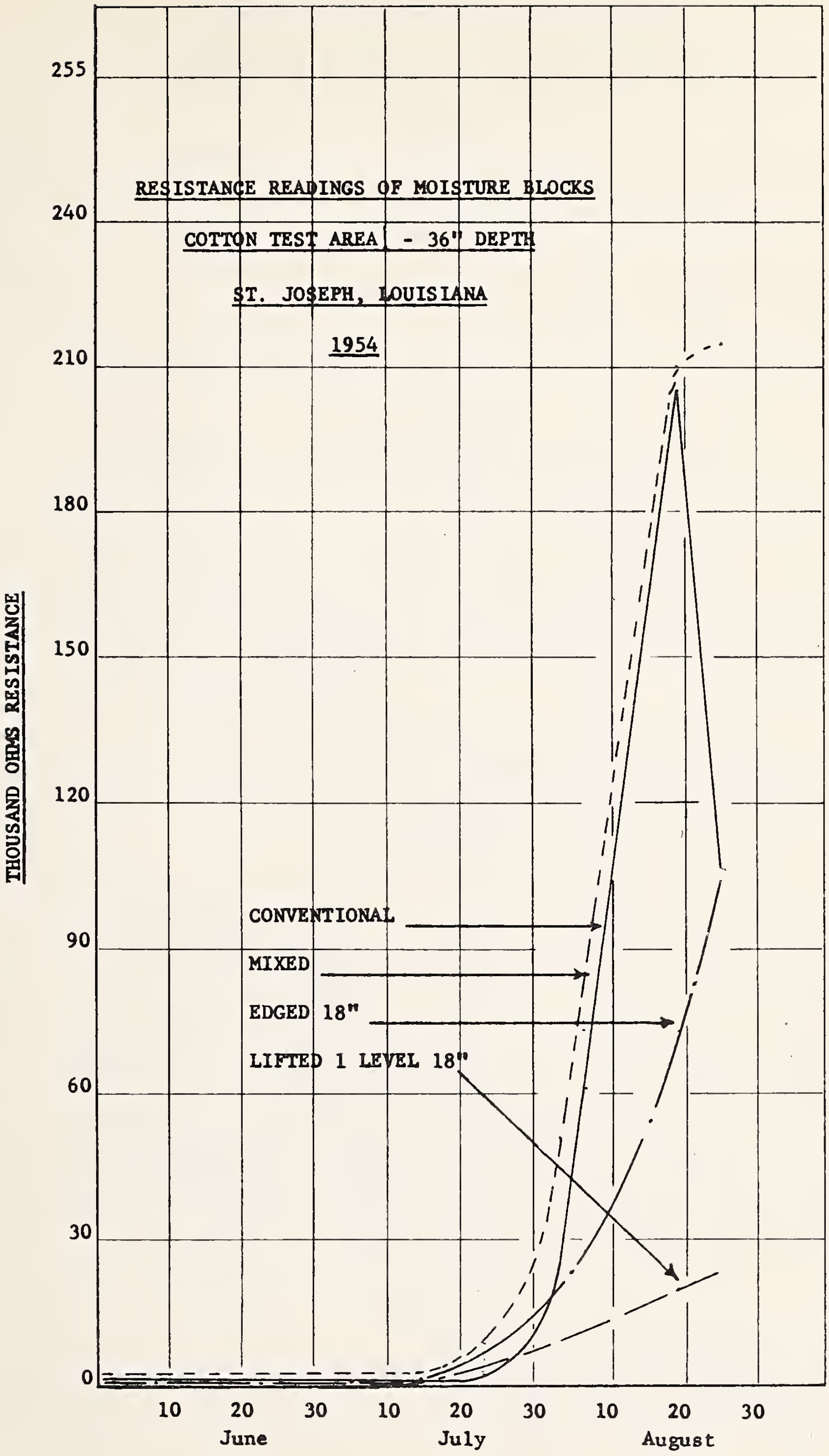

RESISTANCE READINGS OF MOISTURE BLOCKS
COTTON TEST AREA - 36" DEPTH
ST. JOSEPH, LOUISIANA
1954
THOUSAND OHMS RESISTANCE
255
240
210
180
150
120
90
60
30
0
CONVENTIONAL
MIXED
EDGED 18"
LIFTED 1 LEVEL 18"
10
20
30
June
10
20
30
July
10
20
30
August

Figure 11

RESISTANCE READINGS OF MOISTURE BLOCKS

COTTON TEST AREAS - ST. JOSEPH, LOUISIANA

1955

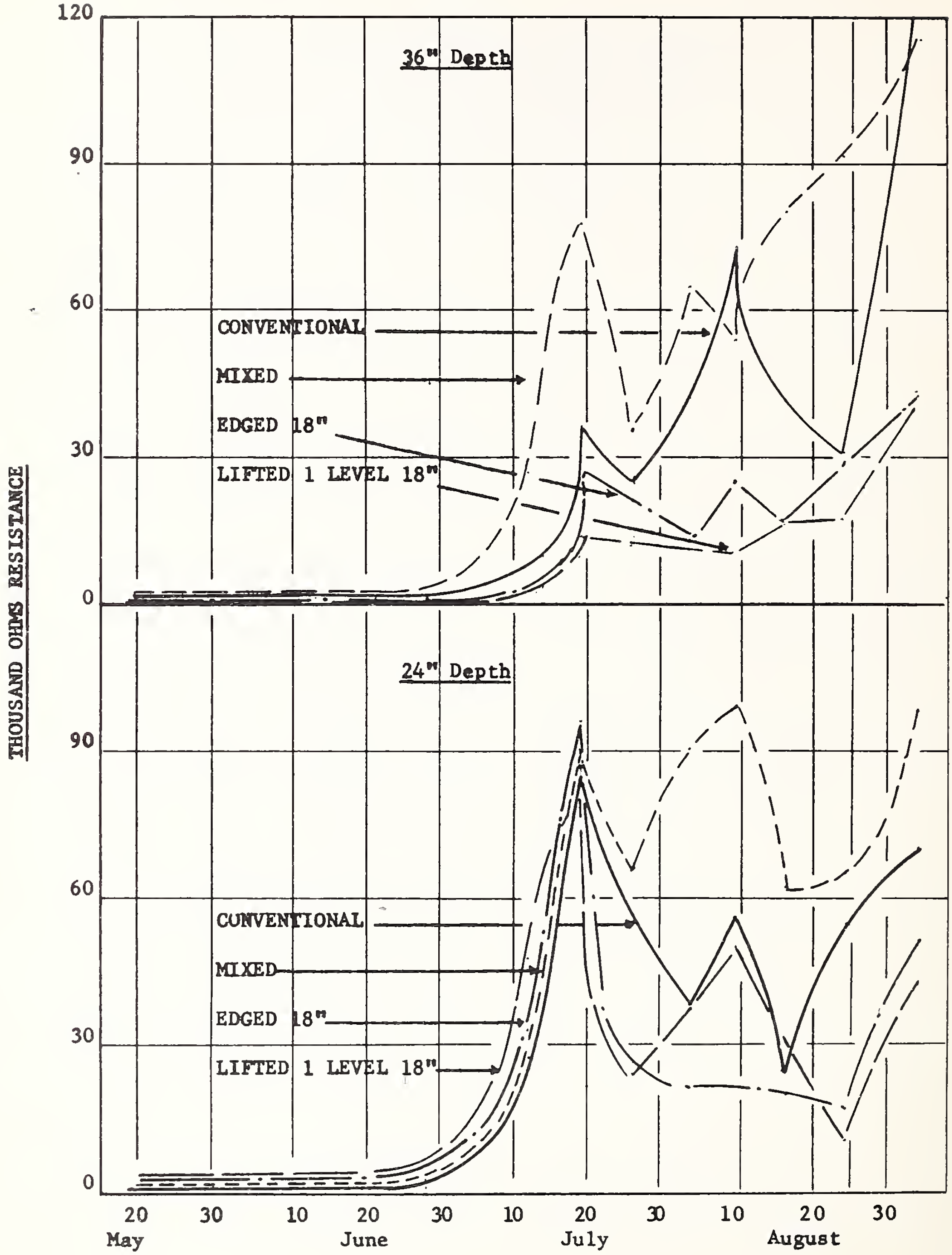


Figure 12

GRAVIMETRIC MOISTURE READINGS

COTTON TEST AREAS - ST. JOSEPH, LOUISIANA

1956

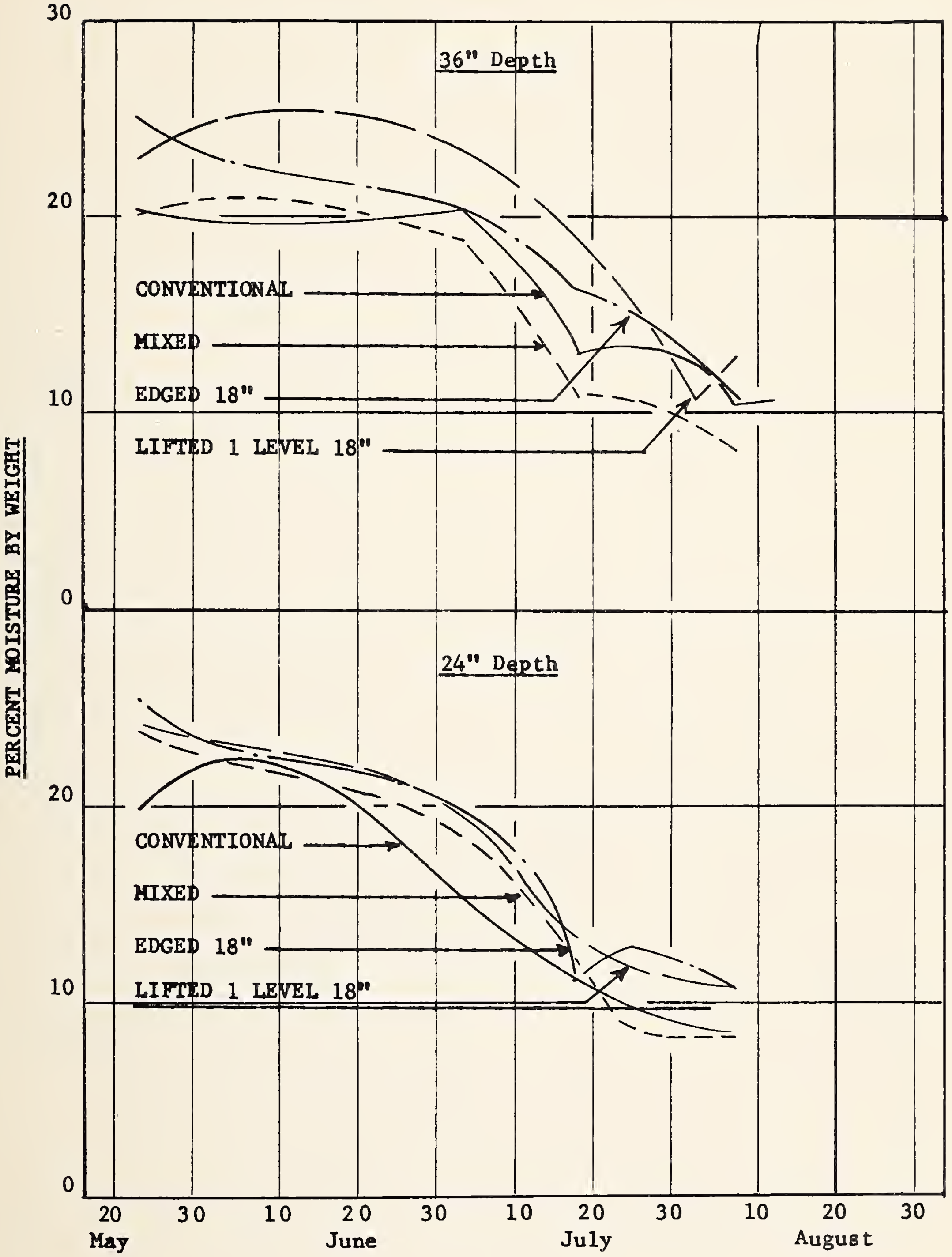


Figure 13

GRAVIMETRIC MOISTURE READINGS

COTTON TEST AREAS - ST. JOSEPH, LOUISIANA

1957

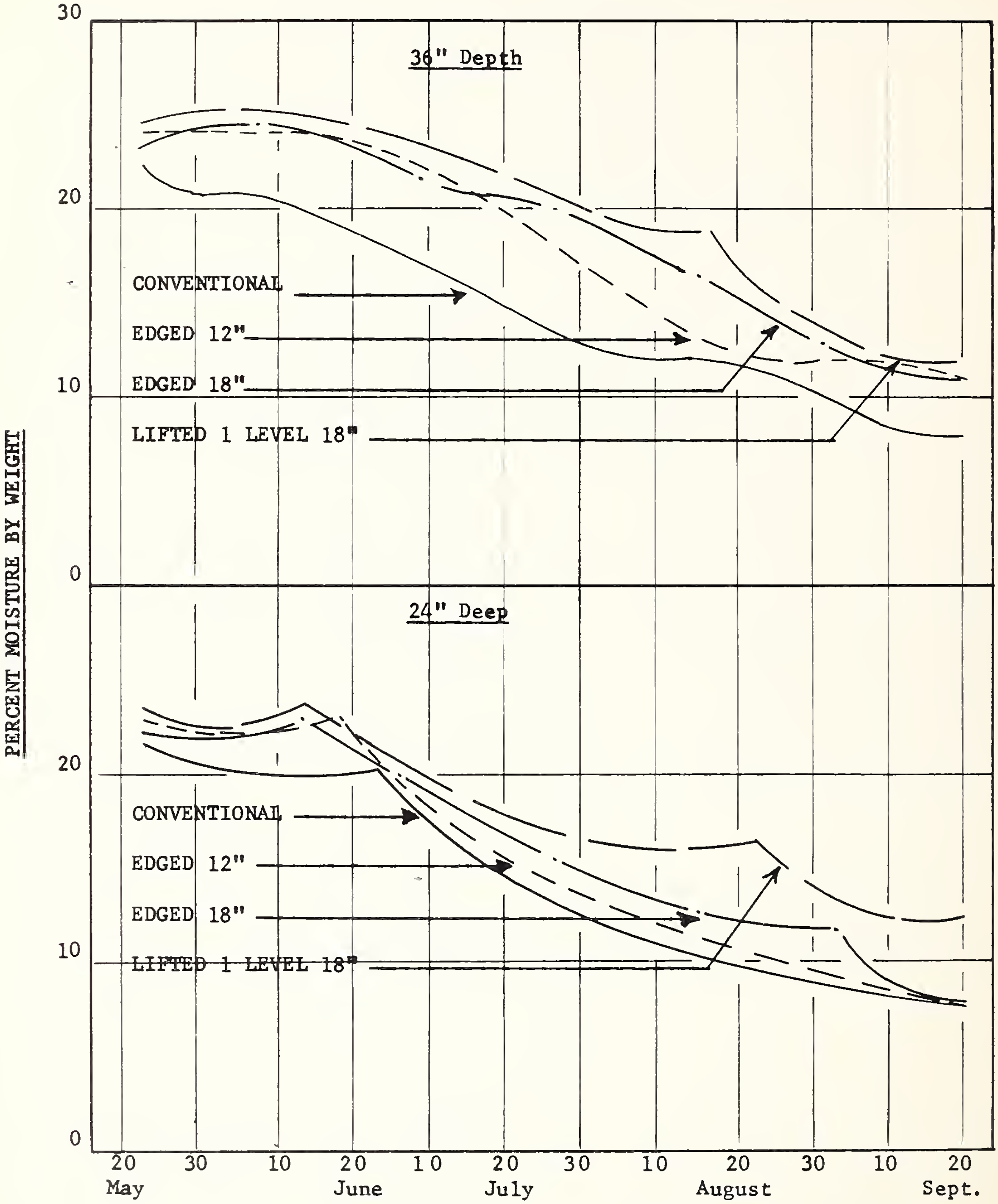


Figure 14

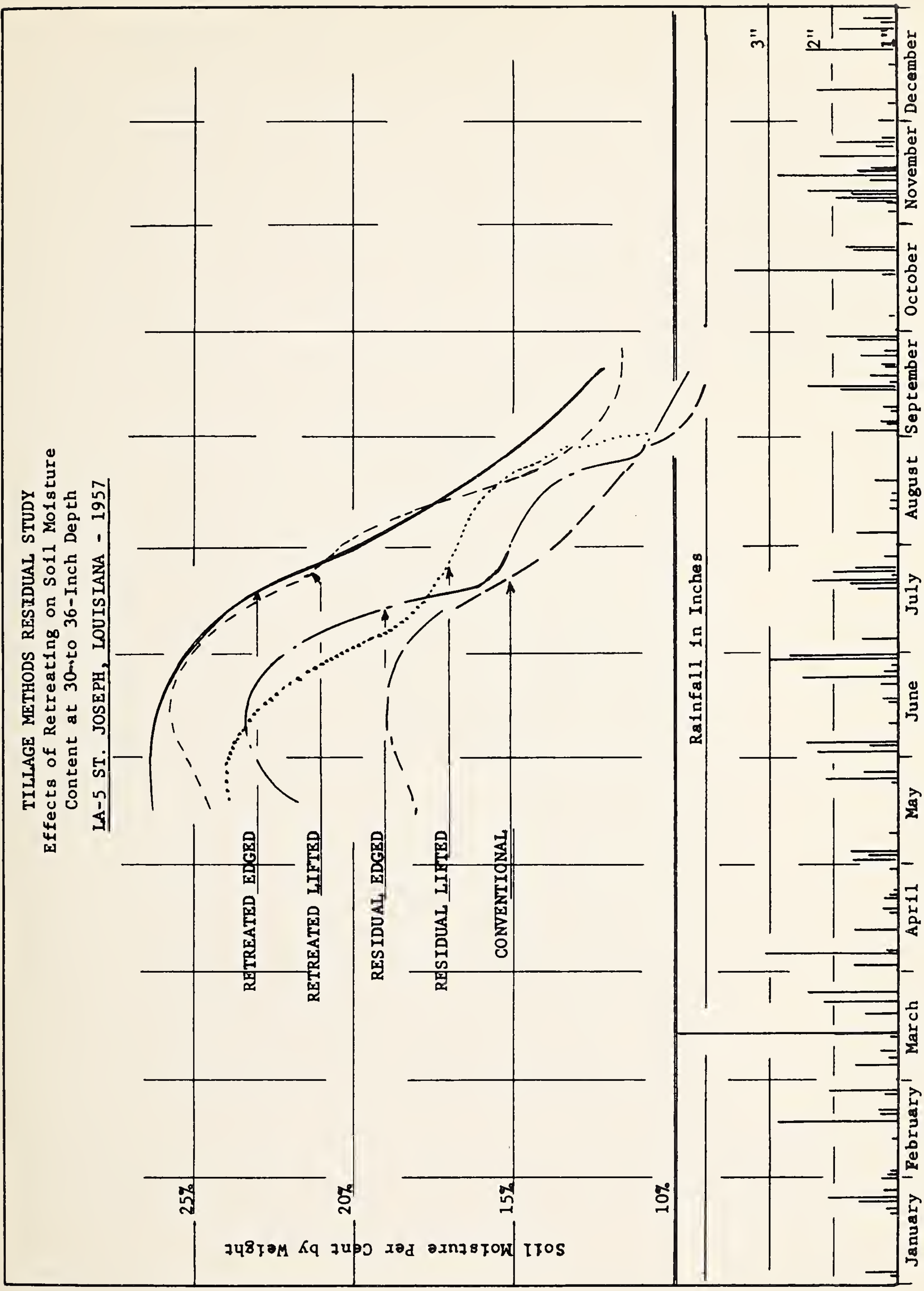

TILLAGE METHODS RESIDUAL STUDY
Effects of Retreating on Soil Moisture
Content at 30-to 36-Inch Depth
LA-5 ST. JOSEPH, LOUISIANA - 1957
RETREATED EDGED
RETREATED LIFTED
RESIDUAL EDGED
RESIDUAL LIFTED
CONVENTIONAL
Soil Moisture Per Cent by Weight
25%
20%
15%
10%
Rainfall in Inches
3"
2"
1"
January
February
March
April
May
June
July
August
September
October
November
December

Figure 15

Growth Through Agricultural Progress